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THE TESTING OF NIGHT VISION

Some Basic Requirements with Introduction and Causes of Abnormality

By E. W. GODDING *(Member)*
From the Crookes Laboratories

(Communicated)

This paper is written with the object of further advancing the establishment of basic requirements in regard to the adequate routine testing of night vision and of obtaining a more general appreciation of the factors concerned. Attempts at accuracy and reproducibility in testing have been as few as methods have been legion. The result has been a marked conflict of experimental evidence. It is felt, therefore, particularly in view of the increase in the number of workers in this field, that the essentials of an accurate instrument and technique should be considered.

PART I.

INTRODUCTION AND CAUSES OF ABNORMALITY

Introduction

The first step is to define the terms used:—

Dark Adaptation: The process by which the eye adapts itself to a change in illumination from high to low intensity. This change is accompanied by an increase in sensitivity; that is to say, the dark adapted eye can perceive light of lower intensity than the light adapted eye. The quantitative expression of the process is made in standard units of illumination (or brightness) and time.

Subnormal dark adaptation means the increased time taken in dark adapting and/or the inability to adapt to "normal" intensity levels.

The general use of the term "night blindness" is discarded, and the term retained only when an absolute sense is appropriate.

Light Adaptation: The converse of dark adaptation, i.e., the process by which the eye adapts itself to a change in illumination from low to high intensity.

Night (Scotopic) vision: The function of the visual apparatus at lower illuminations. The sensory cells mainly concerned are the rods.

Day (Photopic) vision: The function of the visual apparatus at higher illuminations. The sensory cells mainly concerned are the cones.

Illumination and Brightness: Illumination is defined as the amount of light falling on a given area, but as the subjective sensation of light depends on the radiation from the given area to the eye, it is convenient to use a unit of brightness since this is the physical phenomenon directly involved. The unit commonly used is the lambert* and its submultiples: the millilambert (one-thousandth), the microlambert (one-millionth), the micro-millilambert (one thousand millionth), and the micro-microlambert (one million millionth).

The visual apparatus can function over a great range of intensities. Sunlit clouds with a brightness of approximately 10,000 millilamberts or a frosted 100 watt electric lamp of about 30,000 millilamberts can be viewed without great discomfort. At the other end of the scale, the fully dark adapted eye can perceive light the intensity of which is about one-millionth of a millilambert—a range of many millions to one.

For convenience in dealing with the cumbersome figures that result in dealing with such a vast range, log units of the actual brightness in millilamberts, microlamberts, etc., are used. The relationships between the units and the log units are shown in the accompanying table.

The millilambert is frequently used for higher intensities, but the micro-millilambert and micro-microlambert on logarithmic scales are more generally used when dealing with ranges of values. Throughout

* A lambert = 2.054 candles per sq. in

TABLE 1.

Unit:	Lambert (l)		Milli-Lambert (ml)		Micro-Lambert (μl)		Micro-Micro-Lambert ($\mu\mu$l)	
Relationship	Direct	Log Scale	Direct	Log Scale	Direct	Log Scale	Direct	Log Scale
Lambert	1 or 10^0	0	1,000 or 10^3	3	1,000,000 or 10^6	6	1,000,000,000,000 or 10^{12}	12
Milli-Lambert	·001 or 10^{-3}	—3	1 or 10^0	0	1,000 or 10^3	3	1,000,000,000 or 10^9	9
Micro-Lambert	·000001 or 10^{-6}	—6	·001 or 10^{-3}	—3	1 or 10^0	0	1,000,000 or 10^6	6
Micro-Micro-Lambert	·000000000001 or 10^{-12}	—12	·000000001 or 10^{-9}	—9	·000001 or 10^{-6}	—6	1 or 10^0	0

this paper, unless otherwise stated, a log unit refers to log micro-micro-lambert (Log $\mu\mu$l).

Mechanism and Photochemical Basis of Vision

The power of the eye to adapt to light of both high and low intensities is intimately concerned with the presence in the retina of two types of photoreceptors, namely, the cones and rods first discovered by Max Scultz in 1860. There is now convincing evidence as to the existence of two distinct visual mechanisms, colour vision at high intensities associated with the cones (photopic vision) and colourless vision at low intensities associated with the rods (scotopic vision). A complete division of function should not, however, be envisaged, because interconnection and integration is clearly necessary for efficient and smooth running of the visual mechanism, particularly at intensity levels where the two functions are changing over. This interconnection and integration is shown very clearly in the recent work of Walters and Wright (1943) on "The Spectral Sensitivity of the Fovea and Extrafovea in the Purkinje Range." A contributory aid to adaptation is provided by the iris mechanism. According to Stiles and Crawford, at higher intensities changes in pupil area of about 16:1, produce an actual reduction in physical effect of only about half this amount. This is due to the relative ineffectiveness of rays falling obliquely on the retina from the periphery of the lens. At lower intensities, however, the Stiles and Crawford effect does not appear to apply and the physical effect is proportional to pupillary area. Compared with the total range of adaptation this effect is relatively small, but must be taken into account when testing adaptation. The total number of cones has been estimated at some 7,000,000 and the rods at 75,000,000 to 170,000,000. At the fovea something of the order of 140,000 cones per sq. mm. are found, the number decreasing fairly rapidly towards the periphery. The rods are more evenly dispersed, the highest concentration lying between 10 deg. and 20 deg. peripherally. They are absent at the fovea.

An examination of the retinal structure of animals can often provide an indication of their habits. Exclusively cone bearing retinae are indicative of animals with diurnal habits (some of the lizards, for example), whereas nocturnal birds (such as the owl) have either no cones at all or very few.

Visual violet (iodopsin) and visual purple (rhodopsin) are commonly regarded as being the two photoreceptive substances present in the cones and rods respectively, although Wald has shown that prob-

ably more than one substance is present in the cones. The presence of a photosensitive substance in the rods has been known since 1876, when it was discovered in the rods of frogs by Franz Boll. The broad picture appears to be that at high intensities the neural impulses resulting in the sensation of vision are produced by decomposition of the cone photochemical substances, which are rapidly regenerated, so that vision is continuous. This high intensity also decomposes visual purple. On suddenly changing from a high intensity to a sufficiently low intensity vision with the cones ceases, since their photochemical substances are not affected by light of very low intensity. At the same time, there is insufficient visual purple to enable the rods to function and the sensation is one of darkness. After an interval sufficient visual purple is produced to be photochemically decomposed by the low intensity of light, and the passage of neural impulses is resumed. The time before this state is reached depends on the intensity levels concerned and the rate of regeneration of visual purple. The measure of this time interval, properly related to known intensities, constitutes a measure of the individual's rate of dark adaptation.

During adaptation from high to low intensity levels the efficiency of the visual apparatus varies a great deal, and all those distinguishable functions, acuity, brightness discrimination, colour sensation, etc., diminish with decreasing illumination until vision disappears (the peripheral retina is for a time more sensitive to movement than the light adapted periphery, although even then it does not equal the light adapted fovea). In the upward direction the visual apparatus ceases to function when glare sensation intervenes; this may be related to an inhibitory effect found in the optic nerve response.

According to Hecht (1937a) and Mandelbaum (1941a), all the known facts of vision can be explained on the basis of photochemical reactions. In their view, the sensitivity of the retina at any stage of adaptation is determined by the concentration of photoreceptive substances in the cone and rod cells. Any level of light adaptation can be maintained in which an equilibrium state is reached which is characterised by a particular concentration of photochemical substances. According to Wald (1935, 1944), regeneration of visual purple, which is a conjugated protein containing vitamin A, can take place either from the decomposition products (i.e., those which result from exposure to light) or from the raw materials supplied by the blood stream. During the course of dark adaptation no decomposition takes place since there is no light stimulus, and generation takes place up to a maximum. These photoreceptive substances absorb radiant energy resulting in liberation of photochemical energy, this in turn giving rise to electrical impulses mediated by the nervous system, the final response being dependent, as previously stated, on the amount of photochemical substance present at any one moment. This is the essential basis of the theory, but an examination of the literature will show that the changes are much more complex than actually indicated, and as Morton (1944a) points out: "It is doubtful whether, on the chemical side, present theories are more than the merest scaffolding." Although the concentration of photochemical substances does appear largely to govern the sensitivity of the eye at any one moment, Wright and Granit (1938) and others have shown, through their neurophysiological work, that a purely photochemical basis of vision is not sufficient to cover many sensory and physiological phenomena of vision, notably summation effects and intermingling of processes such as is found in investigations on flicker (movement) and acuity.

Vitamin A.—The position of vitamin A in its relation to the photochemical substances has been the subject of considerable investigation, the work of Wald showing that vitamin A is apparently an indispensable constituent. Recent work of Johnson and Detwiler (1943a), in America, has gone so far as to produce experimental evidence as to its visual appearance and utilisation in the cycle of degeneration and regeneration of visual purple already referred to. "The duplicity theory is firmly established

and vitamin A is concerned in both mechanisms" (Morton 1944b). Clinical and adaptive studies also appear to confirm its status as an indispensable factor, but it must be emphasised that it is only one of many factors and its rôle, as yet, is incompletely understood.

Vitamin B_2.—This vitamin has also been shown to be concerned in the synthesis of photochemical substances (Morton 1944c).

One effect which has been investigated by Wright (1941) should be noted, namely, the presence of retinal fog present for some minutes during dark adaptation. This can be demonstrated by covering one eye for 20-30 minutes, then exposing to very low illumination (preferably a starlight night) after 15-20 minutes. The subjective brightness is the same for both eyes, but the acuity is different. The effect is due, he thinks, to disturbances caused by the very active regeneration of photochemical substances, but this disappears as soon as a more or less stable equilibrium has been achieved.

The full assessment of an individual's dark adaptation is carried out by measuring the minimal perceptible brightness at intervals in the dark. To compare the performance of different individuals some standard procedure is necessary, and in particular it is essential to begin the test from a definite level of light adaptation, that is, with the individual's eyes adapted to bright light for a standard time and at a standard intensity; about 1000 ml. for 3 to 5 minutes is commonly used. The recovery times taken for the eye to perceive known intensities decreased in predetermined steps are then found. The first recovery time is that taken to see an intensity of about .01 ml. (10^7 micro-microlambert). To commence the test at much higher intensities is of doubtful value since the recovery in sensitivity at these higher levels is extremely rapid and the position is complicated by the presence of after images (Craik and Vernon (1941 *a*)). The amount of cone vision evaluated when commencing the test at .01 ml (10^7 $\mu\mu$l) will be approximately 1–1½ log units and the amount of rod vision some further 3 log units, according to the particular method of testing. (See Fig. 1.)

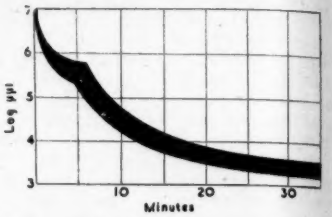

Fig. 1. Dark adaptation curve constructed from results of 150 tests. (After Yudkin, 1941.)

SUMMARY

Two mechanisms are concerned in adaptation, the cones at high intensities (above approx. .001 ml = 10^6 $\mu\mu$l) and the rods at low intensities. The two functions interconnect at intensities which represent the change from one to the other. Although a purely photochemical theory is not sufficient to cover all the known facts, the sensitivity of the eye is largely governed by the concentration of photochemical substances in the sensory cells at any one moment. This increased sensitivity of the dark adapted eye does not enable the visual mechanism to function unimpaired, colour vision is lost, acuity and all the major functions progressively deteriorate. This is due to the fact that the sensory cells concerned with keenest vision go out of action and a coarser mechanism takes over. At the lowest illuminations the fovea represents a complete scotoma.

Causes of Abnormality in Night Vision and Dark Adaptation

The causes of impaired night vision are many, some of which are obvious.

1. AGE.

It is not likely that the function of night vision could escape the effect of age on all bodily mechanisms. Lessened pupil dilation, cloudiness of the media, and deterioration generally must adversely affect vision at night.

2. AMETROPIA AND MUSCULAR ANOMALIES.

Such defects have a varying importance according to the nature of the visual task. They have their least effect when light and simple form perception only are required, and their greatest effect when visual tasks involve a higher standard of acuity,

fusion and stereoscopic vision. When perception of light is the only requirement, the small loss by reflection (approx. 4 per cent.) and absorption (approx. 5-10 per cent.) of light by spectacle lenses would have a small adverse effect. With muscular anomalies, where the stimulation to fixation is low, as it will be at the lower intensities, it is easy to see that fusion may not be achieved. If summation effects provide the reason for the lower binocular threshold over the monocular, then fusion is of importance for even the lowest visual level—i.e., perception of light only. Pirenne's (1943) latest work, however, suggests that summation plays only a small part in obtaining the lower threshold for binocular vision. This, of course, applies only to light perception; when stereoscopic vision is required, fusion becomes an obvious necessity.

3. Hereditary Night Blindness.

This is due to a congenital defect or absence of the rods. There is, of course, no treatment. This condition should be compared with complete colour blindness, where there is a congenital defect or absence of the cones.

4. Pathological Causes.

(a) *Ocular Disease.*—In general, any pathological retinal area has, as would be expected, a diminished sensitivity. A dark adaptation test on a progressive disease such as retinitis pigmentosa can merely reflect the progressive destruction of retinal structure. The effect of advanced disease on dark adaptation is dramatic. Glaucoma, syphilitic atrophy, advanced myopia, detached retina, all affect dark adaptation; the correlation varying according to the nature of the condition. Diseases which give rise to miosis and opacities of the media can obviously affect night vision. Embolism, thrombosis, and toxic states, such as toxic amblyopia and toxic neuritis, may impair dark adaptation as they do other visual functions.

Mandelbaum (1941b) claims that taking retinal sensitivity contours is the most useful procedure for determining pathological retinal areas, and this procedure may have some advantages over perimetric measurements as usually carried out. This development has received a valuable contribution from the work of Livingston (1944). The literature should be referred to for a description of the technique.

(b) *General Disease.* — General disease conditions can affect dark adaptation either directly, e.g., those conditions which are concerned with metabolism, such as cirrhosis of the liver, or indirectly, e.g., general disease conditions which result in impairment of all bodily functions. The precise value of a dark adaptation test as an aid to diagnosis in ocular and general disease has yet to be determined.

5. Impairment of Function due to excessive demands on the Visual Mechanism under Extreme Conditions.

(a) *Changes which take place under low illumination.*—A primary cause of miner's nystagmus is known to be inadequate illumination (M.R.C. Special Reports Series No. 65, 1922). There are undoubtedly contributory causes, and a sufficient supply of vitamin A may have particular significance under these conditions. There is evidence of relative deficiency (Campbell 1941).

(b) *Changes which take place under high illumination.*—Snow blindness and sun blindness are examples. The first is due to ultra-violet radiation and the second to retinal burning, both resulting in damage to the visual mechanism, one of the effects being impaired adaptation.

6. Psychological Causes.

The effect may be extreme: Livingston (1942a) quotes a case where psychological treatment completely restored the vision of a man whose temporary blindness was due to severe mental upset. Wittkower et al (1941) report a series of cases where impaired dark adaptation was due to psychological causes. Some of these authors' inferences have been subject to criticism, but an extended investigation of such cases to determine the effect of psychological treatment might yield valuable information.

The effect may be quite temporary. Mrs. N. examined for a final rod threshold reading by the author on October 7, 1942, at St. John's Hospital, London, gave a very abnormal result which was carefully

checked. Retested next day, a full investigation gave normal results. The subject was a highly excitable type and responded to careful handling and removal of all apprehension regarding the test.

7. NEUROLOGICAL CAUSES.

It is usual to regard the absorption of light by the sensory cells, and the resulting chemical energy which initiates the nerve impulse, as a more or less fixed quantitative relationship. That is to say a nerve impulse results from a definite amount of absorbed radiant energy. As Lythgoe (1940), however, says: "The final electrical response of the retina and optic nerve is determined by the existing synoptic arrangements," and individual variation in these arrangements would mean that a greater initial stimulus of radiant energy would be required in some cases than in others to initiate the final electrical response. Certainly there is an interesting group of individuals who give persistently high threshold values not apparently attributable to general disease, ocular abnormality or faulty nutrition (author's unpublished data). Vitamin A in large doses over prolonged periods has no effect. Among the possible causes might be a high neural threshold, and such a group might repay further investigation by the neurophysiologist.

8. NUTRITIONAL CAUSES.

Detwiler (1943b) says: "The dependence of both rod and cone vision upon the presence of vitamin A in the diet is now very generally known. Whereas night blindness has long been recognised as due to dietary deficiencies, it is in recent years only that this problem has undergone vigorous experimental investigation in animals and men. Recent observations show that vitamin A deficiencies affect the physiological threshold of the visual elements, and that prolonged avitaminosis A may bring about structural breakdown of the rods." This is the generally accepted position to-day. Ocular deficiency symptoms are dryness of the cornea (xerosis), a dry and thickened conjunctiva (xerophthalmia), and finally a softening and degeneration of the tissues (keratomalacia). Pigmentation and ulceration may be present. Bitot's spots are shiny dry spots surrounding the cornea and consist of dried epithelium, flaky masses and micro organisms, and can occur concurrently with other symptoms. We are not likely to see the extreme effect of keratomalacia in this country, but it is worth noting that Hunt and Hayden (1942) in America found a dullness and marked translucency of the conjunctiva in 72 per cent. of vitamin A deficient cases. Krause (1941) says that xerosis precedes impaired adaptation. It is important to note that any sudden or undue demand, such as infection or pregnancy, imposed upon a subject whose nutrition has been faulty, but which hitherto has not caused frank deficiency symptoms, can produce extreme effects which are often multiple in nature since many nutritional factors are likely to be involved. Under such conditions a rapid increase in the impairment of night vision might reasonably be expected. Such considerations could obviously explain, at least in part, the varying effects upon dark adaptation of mild infections such as colds.

Attempts to correlate dietary intake of vitamin A with dark adaptation in apparently healthy subjects have met with the most diverse results, due at least in part to:—

(1) Short-term experiments which may be invalidated by varying requirements of the individual, due probably to variations in metabolism and liver storage capacity. It has been shown in depletion experiments that the body's store of vitamin A may take a long time to use up, and similarly it is possible that some time may be required to fill up the reservoir, the effect of giving vitamin A on dark adaptation being only temporary until this is achieved.

(2) Inadequate techniques and methods of testing.

(3) Factors which have not yet been evaluated. The generation and regeneration of the photochemical substances embrace many factors other than the supply, absorption, metabolism and utilisation of vitamin A. Even in regard to these factors little knowledge is yet available.

It is not surprising, therefore, to

find on occasion subjects with excellent dark adaptation on a relatively poor vitamin A diet, and others with less effective adaptation on a much higher intake. One experimental fact remains: deprive the individual of the vitamin for long enough and dark adaptation must suffer.

As a means of evaluating nutritional status the testing of dark adaptation, in spite of its limitations, appears to be increasingly used; e.g., Kohn, Milligan, and Wilkinson (1943) used it as a measure of the incidence and degree of vitamin A deficiency in Glossop school children, when they found 16 per cent. deficient, 7 per cent. probably deficient and 15 per cent. possibly deficient. Yudkin and Robertson (1943) say: "We consider (referring to dark adaptation results) that the technique and apparatus we have used meet the requirements for a method suitable for detecting deficiency of vitamin A." Dr. L. J. Harris (1944), Director of the Dunn Nutritional Laboratory, says that experience has proved that the dark adaptation method of diagnosing deficiency of vitamin A can be used safely if certain precautions are taken. Such precautions, according to Yudkin (1944) include:

(1) Proof as to the existence of the deficiency of the vitamin.

(2) Proof that the deficiency is the cause of the condition.

(3) Proof that the condition can be cured by giving the vitamin.

Other nutritional factors may prove of equal importance to vitamin A. The recent work of Morton (1944c) in regard to vitamin B_2 has already been noted.

9. Experimental Causes.

Night vision and dark adaptation have been shown by various workers to be affected by certain experimental conditions and treatments. It is useful to include examples of the more interesting results. These are given in Table 2.

SUMMARY

There are many causes of impaired dark adaptation, and with increasing knowledge empirical treatment is giving way to a more rational basis.

PART 2
THE TESTING OF DARK ADAPTATION—BASIC REQUIREMENTS

The practical measurement of dark adaptation has been found to be dependent on many external physical conditions, apart from the biological variations in the subjects themselves. It is, therefore, stressed that one of the first requisites for the scientific investigation of the subject is the control of these conditions. Without this, differences in observation and interpretation by different workers are bound to occur. Such control is best achieved by the standardisation of conditions, and this is discussed in the following paragraphs. It will be seen that certain factors, such as the exposure time of the test light, can be largely eliminated as conditioning factors, provided certain requirements are met.

1. It is first necessary to define what we are attempting to test. Is it merely to test whether the subject's dark adaptation as previously defined is normal or otherwise, or is it to test the subject's ability to carry out visual tasks under certain specified conditions (described by Livingston as "night visual capacity" (1942b))? In the first case we are concerned with the evaluation of the phenomenon of dark adaptation itself, in the second with the unlimited number of special tests which can be elaborated in respect of particular visual tasks, e.g., night flying. As an illustration of this distinction the dark adaptation of two R.A.F. pilots might be tested, and the results obtained found to be identical. Add to the test, however, further requirements, such as the recognition and description of unfamiliar objects, and the performance of the two pilots might vary considerably, since training and psychological factors have been introduced. During a recent dark adaptation survey (unpublished data) a test was carried out on a sailor who claimed great prowess as a look-out man at sea. At the same time a woman was tested who described herself as "terrible in the 'black-out,'" but her final threshold reading was better by 0.2 log unit than the sailor's. Had conditions of a "look-out at sea" been

TABLE 2.

Agent or Method	Investigator	Result	Causes of Effect as suggested by the Investigator
Strychnine „	Woffin (1907) Kayser (1927)	Accelerated adaptation Double power of light perception	
Strychnine Benzedrine Caffeine Phenobarbitone Morphine	Mandelbaum (1944)	No effect.	
Adrenalin 1 : 1000 (instilled into conjunctival sac)	Rothan (1925)	Increase in capacity, not due to pupillary effect	
Alcohol	Mandelbaum (1941)	Threshold raised 2 : 1	Depressed activity of central nervous system
Alcohol Benzedrine	Yudkin (1941) Barondes (1941)	Improved night vision (short temporary effect)	
Mild exercise	Kekcheyer (1943)	Increased rate and range of adaptation	Reflex effect through vegetative nervous system
Oxygen Deprivation	Macfarland and Evans (1939) McDonald and Adler (1939) Mandelbaum (1941)	Raised rod threshold 4 : 1 „ 2.5 : 1 „ 2 : 1	Depressed activity of central nervous system
Respiration Expts. (*a*) Decreased oxygen intake (*b*) Increased oxygen intake (c) Carbon Dioxide inhalation	Wald Harper Goodman and Knieger (1942)	(a) Raised rod threshold 2 : 1 (b) Increased rate (c) 2% no effect 5% raised rod threshold 2 : 1	Central nervous imbalance
Oxygen deprivation at high altitudes (pressure chamber expts.)	Livingston (1942)	At " 15,000 ft." diminishednight visual capacity as determined by means of Hexagon Test. Great enlargement of the blind spot At " 20,000 ft." marked adverse effect	

It is interesting to note the relatively small effect of most of the experiments on the range of adaptation.

successfully simulated as an elaboration of the test, no doubt the results would have reflected the training and psychological factors involved. Night visual capacity, therefore, may be described as the individual response resulting from all the factors concerned in the particular task, visual, adaptative, psychological, and training; in other words, the reactions of the subject as a whole. It will be noted that demands would be made of the visual apparatus additional to light or simple form perception, such as sense of movement, stereoscopic vision, etc. Normal dark adaptation is an obvious requirement for a high standard of night-visual capacity, but no other correlation exists. Clearly, then, when testing for dark adaptation only, it is necessary for the test not to make demands on the subject which would introduce training and/or psychological factors. The test object must be a patch of light or of such a nature that its recognition is automatic, a square or triangle, for instance. Even then it is not always certain that the introduction of external psychological factors has been completely avoided.

2. For the normal healthy person the time taken to become dark adapted depends largely upon the intensity of light to which the eye has previously been exposed. From low intensities (100 to 200 ml.), dark adaptation may be almost complete in 10 to 15 minutes. From moderate intensities (500 to 1,000 ml.), recovery is largely completed in 20 to 30 minutes. With high intensities (10,000 ml., for example) the delay in recovery is appreciable. In all cases the sensitivity of the eye will further increase to some extent over a period of hours. In the testing of dark adaptation, therefore, the standardisation of the previous light or "bleaching" exposure is necessary.

The intensity of the light adaptation or "bleaching" light should be sufficiently high to ensure that subsequent dark adaptation is not so rapid as to make its evaluation difficult, and to make evident the point of transition from cone to rod vision. An intensity of about 1,000 ml for a period of about five minutes has been found to be suitable.

In view of the possibility of previous exposure to higher brightnesses than 1,000 ml. before this light adaptation is commenced, the subject should have been in an internally lit room for about half an hour, with all light sources shielded. Even this added precaution will not neutralise the effects of prolonged previous exposure to very high intensities. The limitations of the technique, therefore, should be noted, and the time spent in dim illumination extended if necessary. This use of dim illumination should not be replaced by half an hour's previous dark adaptation, since it has been shown (unpublished data) that the accelerating effect of immediate preliminary dark adaptation is more difficult to eliminate than the slowing effect of high intensities. This acceleration is particularly marked in the case of subjects where curves show subnormal recovery times. Thus the diagnostic value of the test tends to be lost. The effect, as might be expected, is maximal at the higher intensities, tending to disappear towards the final threshold. It will be seen, therefore, that intervals should always be allowed between repeated tests on the same individual. If a test object without fixation is used, means must be provided for the whole of the retina to be uniformly light adapted, but if a definitely located area only is to be tested, then the usual procedure is to light adapt only that part of the retina in which lies the test area. (Hecht-Shlaer technique).

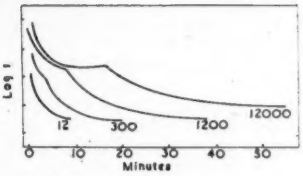

Fig. 2. Dark adaptation curves following exposures to various light intensities (E.F.C.). (After Craik and Vernon, 1941b.)

3. The intensity of the light to be perceived after dark adaptation, called the test light, must be accurately controlled, with some means of progressively and accurately decreasing it. The range of intensity covered, using white light, should be not less than 4 micro-microlambert log

units, or 10,000 : 1. (Approximately one unit for cone vision and three units for rod vision.)

There are various methods of reducing the intensity in steps by the use of neutral density filters and wedges, polarising discs, diaphragms, etc., all of which require standardisation. It should be noted here that the time taken for the eye to become adapted in the opposite direction, i.e., from lower to higher intensities, again varies according to the intensity levels concerned, but in all cases the process is rapid. The sensitivity of the dark adapted eye is therefore easily lost, and regained with difficulty.

It is recommended that the highest intensity for the test light should be not less than 10^7 $\mu\mu$l (.01 ml) decreasing by .05 log unit steps to at least $10^{2.5}$ $\mu\mu$l. This will adequately cover the final threshold for white light. Although .05 log unit steps (approx. 10 per cent.) are unnecessarily narrow for the major part of the process they are required for satisfactory measurements at the rod cone transition stage and at the final threshold.

4. As is well known, the eye is not equally sensitive to all parts of the visual spectrum. Further, whereas the light adapted eye is more sensitive to a wave-length of 560 mμ, the dark adapted eye is most sensitive to a wave-length of 510 mμ. (Purkinje phenomenon).

If a blue "test" light and a red "test" light of equal brightness for the light adapted eye are compared for testing dark adaptation, whereas with the blue light some 3 micro-microlambert log units of rod vision will be evident, with the red light, for equal energy values, only the smallest amount (dependent upon the actual wave-lengths transmitted) will be shown. (See Fig. 3). Colour sensitivity should not be confused with colour sensation. At the lowest intensities no colour as such would be seen.

If, therefore, a monochromatic test light is used, and it is desired to evaluate rod vision over the greatest possible range, a light source with the red end of the spectrum predominating should be avoided. Hecht and Shlaer use a blue light (Corning Filter 511) to obtain the maximum range of rod values. Apart from increased range it is possible that different wave-lengths or white light of different spectral composition may have particular diagnostic values in the testing of dark adaptation, but this has yet to be established. White light appears to be satisfactory for both light and dark adaptation. The third requirement, therefore, is that in all cases spectral values should remain constant, and for this reason rheostatic control of the test light intensities should be avoided. The colour temperature should be stated when white light is used.

5. The Bunsen-Roscoe (Blondel-Rey) Law indicates that if flashes of light are used for the dark adaptation test, then the exposures should be not *less* than 0.2 sec., since the stimulus effect of shorter exposures depends on both the duration of the flash and the intensity, but for exposures of 0.2 sec. and over the stimulus effect will depend on intensity only. This fact should be used only in the testing of a definitely located retinal area when attention is concentrated on the area. Where a test object without fixation spot is being used, longer exposures than 0.2 sec. are certainly required to obtain correct threshold values. The work of Grindley (1931) indicates that at least 1 second is necessary to obtain lowest threshold readings at higher intensities, and experience has shown that at the lowest intensities exposures up to 1 minute or more are required. The usual procedure when using a test object without fixation is to

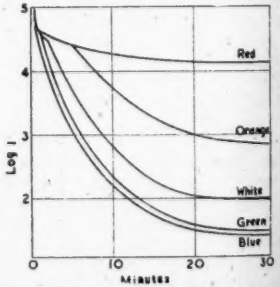

Fig. 3. Dark adaptation curves using different colours for the test object. (Hecht, 1937b, after Kohlrausch.)

use a constant light source at the higher intensities, decreasing the intensity to the next "step" as soon as a particular intensity has been seen. For the lower intensities (e.g., the last 2 log units of rod vision) where the recovery in sensitivity is much slower, intermittent exposures can conveniently be used.

6. Area considerations of the test field or object are also important. As the area increases the threshold decreases until a limit is reached when stimulus effect is proportional to brightness only. With objects subtending at least 7° threshold brightness appears to be almost independent of area considerations (Piper 1903, Lohle 1929). This is in general agreement with the work of Graham Brown and Mote (1939). Hecht (1937c), however, was able to produce equally low threshold values with a test field subtending only 2° by carefully locating this on the most sensitive part of the peripheral retina. It is recommended, therefore, that unless the test field or object is fixated as described by Hecht the visual angle subtended should be at least 7°.

7. The limitations on the distance at which the test should be carried out are not clear. No data exist for rod vision which show at what minimum distance there will be no pupil contraction reflex effect, due to fixational distance stimulus. At higher intensities (0.1 ml), Luckiesh and Moss (1937) have shown that the size of the pupil, although smaller for binocular vision than for monocular, is not altered significantly by any increase in distance over 60 cms., and it would seem that this may be regarded provisionally as a safe minimum distance for adoption as standard.

8. For subjects with healthy pupillary reflexes artificial pupils would appear unnecessary, providing the distance requirement is met. If it is desired to correlate findings with those of workers using an artificial pupil, Mandelbaum (1941c) has supplied a correction factor which will enable this to be done; the use of a miotic and measurement of the pupil diameter will, of course, be necessary.

9. It is necessary to decide whether the test is to be a monocular or binocular one. Most workers have found, as would be expected, that the final threshold reached is lower for binocular vision than for monocular vision, but certain methods of testing preclude the use of both eyes; for example, where a definite retinal area is being investigated. Psychological errors are perhaps more likely to be avoided by the use of both eyes, since a monocular test does introduce for some subjects a somewhat unusual element. Where permissible a binocular test is recommended.

10. All subjects should preferably be rendered emmetropic and presbyopia corrected in relation to the distance at which the test is being carried out, but small and medium errors of refraction, as would be expected, appear to have little effect on threshold readings when flashes of light or relatively large simple test objects are used. (See under Causes of Abnormality.) It is recommended that vision under 6/18 should always be corrected. The loss of light by reflection and absorption of lenses is approximately 10 per cent. to 15 per cent. The effect of this on threshold values is relatively small (approx. .05 log unit), but should be allowed for where subnormal results are obtained.

11. Different areas of the peripheral retina of the dark adapted eye vary in sensitivity. The most sensitive area is an annulus between 10° and 20° around the fovea. There is, however, no great diminution in sensitivity between 6° and 40°. Such are the findings of Sloan (1939) and these are in general agreement with those of Mandelbaum (1941d). This varying retinal sensitivity has given rise to sharp differences in the methods of testing dark adaptation. Hecht and Shlaer, for example, insist on the necessity of testing a definitely located retinal area (obviously requiring a fixation spot), whereas many workers in this country—Yudkin, Wilkinson, and others have used a test object without a fixation spot. Since, under the stimulus of light, the eye automatically tends to use the most sensitive part of the retina, varying sensitivity in the peripheral retina does not appear to be an argument in itself for testing a definitely located retinal area. Moreover, quite apart from the

difficulties in maintaining accurate fixation, the use of an area located 7° from the fovea (the standard procedure using the Hecht-Schlaer apparatus) does not take into account possibilities of unusual retinal sensitivity distribution. For example, should diminution in sensitivity be unduly great at 7° in any particular subject, then the results obtained would not be a true indication of the subject's power of dark adaptation.

When not using a fixation spot, it must be admitted, however, that experience has shown that some direction is occasionally necessary in the case of a small percentage of subjects (usually over anxious) in order to obtain relaxation and use of peripheral vision. Undue effort on the part of the subject resulting in strain and fatigue must at all times be avoided.

12. An important consideration is the visual level at which the test is to be carried out. With the use of light flashes only, Hunt and Palmer (1940a) investigated the various stages of perceptibility following 30 minutes dark adaptation and the actual intensities concerned, with the following results:—

		Mean Threshold Log-$\mu\mu$l
Stage 1	Just perceptible, form absent.	2.847
Stage 2	Definitely perceptible.	2.879
Stage 3	Form present.	3.134
Stage 4	Bright image with form.	3.298

They concluded, therefore, that as much as .5 log unit variation in the threshold after 30 minutes may be due to differences in subjective criteria of perception. It will be observed that in regard to the last two stages a question of resolution is involved. It is, therefore, not necessarily correct to regard the use of light flashes from a test field as involving " light perception " only.

In regard to the use of a test object requiring recognition (providing the form is of a sufficiently simple character as to ensure its automatic recognition), only Stages 3 and 4 above would seem to apply, and the differences in subjective criteria thereby apparently reduced to .16 log unit. The work of Hecht, Shlaer, and Pirenne (1942) on energy, quanta, and vision, appears also to be concerned in the relationship between the two methods of testing. They conclude in regard to the minute amount of energy required to elicit a response at the final threshold, that it is the stimulus which is variable and not the organism. Until, however, the two methods of testing are investigated under the same conditions, it would seem that an adequate assessment of these factors as they apply to the testing of dark adaptation is not possible.

Types of Instruments. — Various types of instrument have been designed for observing the progress of dark adaptation. Three of the best known are described below.

1. *Hecht Shlaer Adaptometer* (1938) (U.S.A.).—Uses light flashes only, 2° test field fixated 7° peripherally. Preliminary light adaptation to approx. 1,000 ml. (white light). Monochromatic test light (Corning violet filter No. 511). Variation of test light intensities effected by means of neutral density filters and wedges. The test is monocular. The intensity of light visible at fixed intervals is determined.

2. *Craik and Vernon's Apparatus* (1941c) (Cambridge).—Constant light source. Range of intensities 10^6 : 1 (from 0.05 E.F.C. downwards).* The instrument has been modified in order to eliminate the difficulties associated with an optical system and the use of artificial pupils. The test light illuminates an opal glass disc through a wedge which the subject adjusts by means of a long shaft, so as to maintain a just visible brightness. A "V" shaped form can be placed in front of the screen for testing acuity. The equipment for light adaptation consists of opal glass plates illuminated to 750 E.F.C. A clockwork drum automatically plots the curve.

3. *Haines Dark Adaptation Tester* (1938) (Crookes D.A.T. London).—Constant light source. Test object requiring resolution. White light is used for both the preliminary light adaptation and test object. Range of intensities 10,000 : 1 by means of neutral density filters and polaroid discs. The test is binocular or monocular. The instrument has been modified by various workers, e.g., Yudkin

* One E.F.C.=1.07 millilambert.

and Robertson, Kohn, Milligan, and Wilkinson. A new development of the instrument which makes conditions closely reproducible in different instruments has now been completed and will provide alternative methods of testing, light flashes with fixation, or test objects requiring resolution; range of intensities 10^6 : 1 (from 0.4 ml. downwards).

An obvious requirement for all these tests is a completely blacked-out room, or special cabinet (such as is used by some American workers) which permits the investigator to work in ordinary illumination while the subject remains in the dark.

Application of the Test.—The first essential is that any particular instrument should give reproducible results. Since the test is on biological material some difficulties are introduced at the outset. The reproducibility of instruments can, however, be tested with reasonable accuracy by carrying out repeated tests on the same subject at short intervals. Such results must inevitably include the minimum variation of the subject, who should be carefully selected to exclude all possibilities of ocular or general abnormality and whose nutritional status is beyond question.

The closeness with which results can be reproduced, apart from the subject, is conditioned by limitations of the apparatus such as errors in standardisation of illumination, and of optical and other parts. It is doubtful whether a practical standard can be established to obtain an accuracy better than ± 5 per cent. either on one instrument or between different instruments.

As regards the subject there is a day to day variation to be expected, together with subjective errors of perception.

In addition hazards exist which are not under control or only partly so. As an example the iris of certain subjects has been observed to contract during dark adaptation for some reason unknown and to remain under spasm for variable short periods before relaxing. The observations were, of course, carried out under special conditions. The incidence is not known. (Verbal communications, Dr. W. S. Stiles, B. H. Crawford, and E. R. Fincham.) Such hazards indicate the necessity of checking abnormal results.

The next requirement is to establish a normal range of responses, that is to say, the range of distribution of responses among subjects who are clinically healthy and in a satisfactory state of nutrition. Normal values might with advantage be established for different age groups, e.g., 10-20, 20-30, 30-40, 40-50, and over 50.

It is then possible to correlate the responses of subjects showing clinical abnormalities with these normal values and thus establish a diagnostic value for the test.

This is the procedure which has been generally adopted, though probably with insufficient attention to certain details. In particular, it is felt that it is necessary to establish an unimpeachable normal range for different age groups. The clinical normality of the subjects used for this purpose must be ensured by general medical and ocular examination, and safeguards applied to their nutritional status.

Simplification of the Test.—Numerous attempts have been made to produce simple tests. Experience has shown, however, that the warning given by Mandelbaum (1941e) is largely justified, viz.: "A simple technique and apparatus in the light of modern knowledge is usually grossly inadequate, and at best is capable of providing merely an approximation."

Before the question of simplification can be dealt with it is necessary to ask, "What information is required in order that a subject's dark adaptation can be evaluated? Is it sufficient to determine the lowest intensity of light which a fully or almost fully adapted subject can see; in other words, determine the 'final' rod threshold only, or is it necessary to evaluate the whole course of dark adaptation?" If the "final" rod threshold is a true indication of the whole course of adaptation, then clearly that is all that need be tested. Unfortunately, it is not always so, as

will be readily seen from a consideration of Fig. 4.

Sufficient data have, however, been accumulated to indicate that this measurement is the most valuable single one to make where a relatively simple test is required. Any attempt

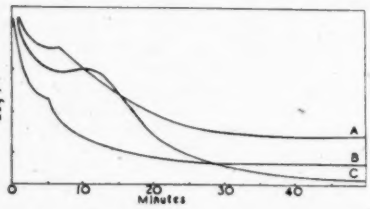

Fig. 4. Individual dark adaptation curves. (After Craik and Vernon, 1942.)

to simplify the test by taking single readings at higher intensities (e.g., between 10^{4-6} $\mu\mu$l) has been shown to be subject to gross errors. Since the sensitivity of the eye is rapidly changing at such higher intensities, such errors would appear inescapable under the conditions which must apply to routine testing. Further, Hunt and Palmer (1940b) have shown (using light flashes only) that the mean deviation is less at 30 minutes adaptation than at any previous dark adaptation time. It is clear, therefore, that the nature of the phenomenon precludes the use of short, simple tests.

The usefulness of taking "final" threshold reading at ¾-hour instead of 30 min. is open to question. One type of subnormal adaptation shows a shift along the time axis only, that is to say, given a sufficient time the final threshold readings are normal. At 30 min. dark adaptation there is a much better chance of diagnosing this delayed type. The only type of "slow" curve which will then escape detection is that where the shift on the time axis is restricted to the higher intensities (type C.—Fig. 4).

Whether a full curve or only threshold readings at 30 minutes D.A. time is taken will depend on the information required. For mass surveys the latter method appears to be the only practical procedure, but full curves are preferable when conditions permit, and essential when information is required regarding threshold values at higher intensities.

Tests for taking final threshold readings only do not require previous light adaptation to a standard intensity, but previous to the 30 minutes dark adaptation as for full tests 30 minutes or more should be spent in dim internal illumination. The range of test light intensities need cover only the possible variations in final threshold readings (some 1-2 log units). All the remaining requirements in respect of "full" tests will apply. A useful procedure is to show the subject an intensity which can be seen fairly easily, and then to reduce this until the final threshold has been determined. Apparent subnormals should be rechecked, preferably with a "full" test.

Should there prove to be a sufficient use for instruments which give final threshold readings only, then the elimination of features not required from instruments which give full curves is perhaps a better procedure than evolving simpler tests as such. Obviously all instruments capable of giving "full" curves can be used for taking final thresholds only.

Additional Requirements.

The demands on the subject are of the simplest character, but as with all subjective tests co-operation is essential.

Although carrying out the actual test is a straightforward procedure, the testing of night vision in general is not suitable for unskilled operators.

SUMMARY

There are a number of factors which require close control in the adequate testing of dark adaptation. Obviously, a universally accepted test and technique would be an immense advantage from the point of view of the correlation of results, and suggested standards are put forward with this end in view. Nevertheless, considerable progress has been made towards general agreement on basic requirements, but certain problems, notably the relative values of the use of light flashes as against a test object without

fixation, require further investigation. Two methods of testing are discussed, the taking of "full curves" and "final" threshold readings only.

General Summary

Knowledge of the phenomenon of night vision is now sufficient to enable the various factors which condition it to be brought under control, and its evaluation made possible. Considerable progress has also been made in the evolution of adequate tests and techniques, and the results obtainable are already reproducible within fairly narrow limits. Suggestions are made regarding future procedure for establishing "normal" curves. The further application of the testing of dark adaptation to academic problems would appear almost unlimited, and its value as a diagnostic aid in nutritional studies has already appeared. Perimetry at low intensities should be noted as a recent development which appears to offer a valuable means of diagnosing diminished sensitivity in particular retinal areas. The value of special elaborations to test "night visual capacity" in regard to particular visual tasks has also been established.

The author desires to acknowledge the generous co-operation of Dr. Kenneth Craik, of Cambridge University, and Mr. J. I. M. Jones, M.Sc., who have kindly checked the proofs and also the assistance of Dr. John Yudkin and Mr. R. T. M. Haines, M.A., for their helpful criticisms.

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Exchange of Publications with the Illuminating Engineering Society in America

The Illuminating Engineering Society in the United States has kindly consented to extend the existing arrangement for the exchange of publications. In future 25 copies of "Illuminating Engineering," the journal of that Society, will be available, and this will enable copies to be sent to the secretaries of all the existing Centres and Groups in this country, by whom they should be preserved for inspection by local members.

A similar number of copies of the Transactions of the Illuminating Engineering Society in this country, and of LIGHT AND LIGHTING, will be sent to specified addresses in the various regions in America. It is hoped that this procedure will promote still further knowledge mutual of the activities of both societies.

Forthcoming Sessional Meeting

The next Sessional Meeting, to be held at 5.30 p.m. on Wednesday, March 21, will be a joint meeting with the Royal Meteorological Society, and will take place in the large Physics Theatre of the Imperial College of Science, Imperial Institute-road, South Kensington. A paper entitled "Measurement of the Photometric Properties of the Upper Atmosphere" will be presented by Mr. J. M. Waldram (Fellow).

Papers for Forthcoming Session 1945-1946

Arrangements are now being initiated for the programme of Papers for the forthcoming session, which commences in October next.

The hon. secretary will be pleased to receive from members offers of papers for sessional meetings in London, or any suggestions for meetings and other events during the coming session.

Offers of papers to be read before Centres and Groups should be addressed to the respective hon. secretaries whose names and addresses appear in the complete list published in the present number (pp. 46-47).

Papers containing novel subject matter and describing original researches or personal experience are specially desired, but contributions summarising developments or reviewing existing knowledge are also welcome.

Annual General Meeting and Meeting of Areas Joint Committee

The annual general meeting will take place in the lecture theatre of the Institution of Mechanical Engineers (Storey's-gate, Westminster, S.W.1) at 5.30, on Tuesday, May 15, 1945. On the subsequent day (Wednesday, May 16) the customary meeting of the Areas Joint Committee will be held. Further particulars will be circulated in due course.

Sessional Meetings in London

A Sessional Meeting took place at the E.L.M.A. Lighting Service Bureau (2, Savoy-hill, London, W.C.2) at 5.30 p.m. on Tuesday, January 9, 1945. The President (Mr. E. Stroud) was in the Chair.

After the Minutes of the previous Meeting had been taken as read, the President called upon Mr. R. Gillespie Williams to present his paper on "The Poetry of Light."

This paper, which was aided by numerous experiments and demonstrations, illustrated the power of lighting to give "emphasis" or "character" to the objects illuminated. The lecturer explained and illustrated the effect of various factors, such as reflecting power, hue and colour of light, and the influence of colour combinations, including contrasts of complementary colours. The application of these principles to many practical lighting problems, e.g., in theatres, cinemas, stores, etc., was pointed out.

Mr. L. C. Applebee subsequently commented on the paper, illustrating his remarks by recollections of famous plays and spectacles of the past, in which coloured light had played a part. After Mr. Gillespie Williams had briefly replied, a vote of thanks to the author and to the E.L.M.A. Lighting Service Bureau for their hospitality terminated the proceedings.

A further Sessional Meeting took place in the lecture theatre of the Institution of Mechanical Engineers at 6 p.m. on Tuesday, February 13, 1945, the President in the Chair.

After the Minutes of the last Meeting had been taken as read and the Honorary Secretary had announced forthcoming meetings, the President called upon Dr. C. C. Paterson to introduce the recently issued Report of the Department of Scientific and Industrial Research on the Lighting of Buildings. In doing so he congratulated Dr. Paterson on receiving the twenty-third award of the Faraday Medal, granted by the Council of the Institution of Electrical Engineers for "conspicuous services rendered in the advancement of electrical science, particularly in electrical research."

Dr. Paterson then gave a summary of the Report, explaining the main objects of the Committee, and dealing in turn with the various sections and appendices. He was followed by Mr. P. V. Burnett and Mr. R. O. Ackerley, who described respectively the work of the sub-committees concerned with Natural and Artificial Lighting.

The discussion was opened by Mr. J. S. Dow, who was followed by Mr. P. J. Waldram, Mr. C. Harvey, Mr. A. E. Godding, Mr. A. Cunnington, Mr. M. W. Hime, and Mr. R. W. Hunt. After Mr. P. V. Burnett and Dr. C. C. Paterson had briefly replied to the discussion, a vote of thanks to the authors was passed with acclamation.

A pleasant feature of the evening was the presence of Dr. N. A. Halbertsma, well known to many of those present for the leading part he had taken in the I.C.I., and especially in the gathering held in Holland shortly before the war. Dr. Halbertsma, who gave a brief account of experiences in Holland, received a very warm and cordial welcome.

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Mr. T. Wilkie (1943)
Mr. G. T. Winch (1944)

Representatives of Areas :—
(ex-officio)

Midland—Mr. A. J. Pashler
North Eastern—Mr. E. C. Lennox
North Midland—Dr. E. C. Walton
North Western—Mr. N. C. Hodson
Scottish—Mr. E. M. Hood
South Wales—Prof. T. David Jones
Western—Mr. E. J. Ireland

Hon. Treasurer :—
Mr. N. V. Everton (1943)

Hon. Secretary :—
Mr. J. Stewart Dow (1928)

The names in italics are those of retiring Officers or Members. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

ELECTION OF OFFICERS AND COUNCIL

SESSION 1945-1946. OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, and Ordinary Members of Council, is presented below for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48):—

> "After the issue of the Council's list, and not later than the 15*th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nominations in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Nominated by the Council to fill Vacancies:—

President:—

Mr. H. C. WESTON, F.I.E.S.

Vice-Presidents:—

Mr. HOWARD LONG, M.I.E.E., F.I.E.S.
Mr. H. E. CHASTENEY
Mr. J. M. WALDRAM, B.SC., A.C.G.I., F.I.E.S.

Members of Council:—

Mr. J. N. ALDINGTON
Mr. M. G. BENNETT
Dr. W. M. HAMPTON
Mr. A. G. HIGGINS
Mr. J. S. PRESTON
Mr. A. J. P. PASHLER
Mr. E. B. SAWYER
Dr. W. S. STILES
Dr. W. D. WRIGHT

Representatives of Areas:— (ex-officio)

To be appointed by the Area Committees before October 1, 1945.

N.B.—*Nine* nominations are necessary in order that the vacancy left by the death of Mr. H. Lingard, as well as those due to annual retirement, may be filled.

Hon. Treasurer:—
Mr. N. V. EVERTON

Hon. Secretary:—
Mr. J. STEWART DOW

SESSION 1944—1945

LIST OF I.E.S. REGIONAL COMMITTEES

AREAS:

MIDLAND AREA.

Chairman: A. J. Pashler. *Committee:* C. S. Caunt, E. Howard, J. Martin, J. H. Nelson, E. G. Phillips, M. R. H. Sadler, F. J. Stanyon, W. J. P. Watson, C. S. Wheeler. *Hon. Secretary:* C. J. Allderidge. 125, Moor Street, Birmingham.

NORTH MIDLAND AREA.

Chairman: E. C. Walton. *Committee:* T. C. Holdsworth, A. J. Holland, J. H. Mollan, R. Pye. E. G. R. Taylor. W. G. Thompson. *Secretary:* J. A. Whittaker, Magnet House, Fitzalan Square, Sheffield, 1.

CENTRES:

BATH AND BRISTOL CENTRE (WESTERN AREA).

Chairman: E. J. Ireland. *Vice-Chairman:* R. E. Tucker. *Hon. Treasurer:* S. M. Richman. *Committee:* R. G. Capell, R. S. Hazell, E. A. Jacobs, W. A. Laughton, L. C. Rettig, W. S. Shaw, H. J. Weston. *Hon. Secretary:* D. J. Sawkins, 86, Redcliffe Street, Bristol. *Hon. Asst. Secretary:* A. E. Hayward.

BIRMINGHAM CENTRE (MIDLAND AREA).

Chairman: J. G. Holmes. *Vice-Chairman:* F. F. Middleton. *Hon. Treasurer:* F. L. Cator. *Committee:* J. Ashmore, P. L. Field, H. A. Keeling, Howard Long, R. Mackenzie, J. H. Nelson, C. F. Partridge, W. E. Prendergast, T. H. Varcoe. *Hon. Secretary:* C. J. Allderidge, 125, Moor Street, Birmingham.

CARDIFF CENTRE (SOUTH WALES AREA).

Chairman: T. David Jones. *Vice-Chairman:* T. Scott Harrison. *Past Chairman:* E. Jones. *Committee:* C. C. Bleach, J. S. Childs, W. Elliott, M. C. Hughes, W. E. James, J. Trevor Jones, J. S. Liversage, G. R. Lusty, H. W. Mabbett, C. E. Springsguth, B. C. Wilkins. *Hon. Secretary:* S. G. Turner, Mervyn House, Frederick Street, Cardiff.

GLASGOW CENTRE (SCOTTISH AREA).

Chairman: E. M. Hood. *Vice-Chairman:* J. Lawrence. *Committee:* S. G. Batt, J. Dickson, L. Fletcher, F. Hailstones, F. M. Hale, J. M. Henshaw, V. P. Macnaughton, A. M. Rankin, D. Ross. *Hon. Secretary and Treasurer:* M. W. Hime, 29, St. Vincent Place, Glasgow, C.1.

LEEDS CENTRE (NORTH MIDLAND AREA).

Chairman: E. C. Walton. *Vice-Chairman:* T. C. Holdsworth. *Past Chairman:* A. Kelso, J. W. Whitaker. *Hon. Treasurer:* J. G. Craven. *Committee:* A. E. Elson, E. A. Fowler, J. D. Green, A. Grocott, H. W. Harris, D. C. Henderson, A. J. Hutchison, J. H. Jackson, A. J. Johnson, J. H. Jones, J. H. Mollan, B. C. Osset, J. H. Rogerson, A. Wilde, E. Wood. *Hon. Secretary:* R. Pye, 46, Wellington Street, Leeds, 1.

LEICESTER CENTRE (MIDLAND AREA).

Chairman: J. Martin. *Vice-Chairman:* H. H. S. Mansfield. *Committee:* E. H. Billing, W. N. Coulson, W. I. Hodgkins, P. H. H. Jantzen, A. W. Squire, F. A. Smith, T. Wilkie, F. J. Yates. *Hon. Secretary:* F. J. Stanyon, 48, Eastfield Road, Leicester.

MANCHESTER CENTRE (NORTH-WESTERN AREA).

Chairman: N. C. Hodson. *Vice-Chairman:* H. C. White. *Past Chairmen:* W. H. Smith, J. A. Somerset. *Hon. Treasurer:* W. M. Fisher. *Committee:* H. Atherton, W. Browning, H. Etchells, J. H. Lumsden, K. R. Mackley, J. H. Morrison, W. C. Sherry, M. C. Toner, J. Walsh. *Hon. Secretary:* Alan H. Owen, 11, Albert Square, Manchester.

LIST OF I.E.S. REGIONAL COMMITTEES—SESSION 1944-45

NEWCASTLE CENTRE (NORTH-EASTERN AREA).

Chairman: E. C. Lennox. *Vice-Chairman:* W. Cross. *Past Chairman:* J. Mitchell. *Hon. Treasurer:* J. Stewart. *Committee:* S. M. Cox, C. Fielding, R. W. Gregory, H. L. James, J. N. K. Rankin, D. L. Tabraham, F. H. Webb. *Hon. Secretary:* S. D. Lay. Ellison Buildings, Ellison Place, Newcastle-on-Tyne.

NOTTINGHAM CENTRE (MIDLAND AREA).

Chairman: E. G. Phillips. *Vice-Chairman:* R. Gillespie Williams. *Hon. Treasurer:* E. Howard. *Committee:* C. C. Barnes, J. C. Charity, A. Collard, R. H. Ellis, A. Hacking. G. D. Johnson, J. B. Saunders, C. C. Small, M. Wadeson. *Hon. Secretary:* C. S. Caunt, 62, Thackerays Lane, Woodthorpe, Nottingham.

SHEFFIELD CENTRE (NORTH MIDLAND AREA).

Chairman: W. G. Thompson. *Vice-Chairman:* A. J. Holland. *Past Chairmen:* H. Wheeler, J. K. Marsden, J. T. Grimshaw. *Hon. Treasurer:* W. Berry. *Committee:* C Couzens, L. E. E. Langdon, H. B. Leighton, R. Hillier, F. J. E. Walker, H. F. Walker, J. S. Whitehead, H. A. Wilson, L. Wilson. *Hon. Secretary:* J. A. Whittaker, Magnet House, Fitzalan Square, Sheffield, 1. *Hon. Asst. Secretary:* D. H. Fox.

GROUPS:

BRADFORD GROUP (NORTH MIDLAND AREA).

Chairman: J. H. Rogerson. *Committee:* T. N. Hird, W. J. Ineson, W. H. Jamieson, R. Margetts, H. Moss, W. H. Naylor, A. Southern, F. S. Warburton. *Hon. Secretary:* A. J. Hutchison, 27, Bolton Road, Bradford.

DERBY GROUP (MIDLAND AREA).

Chairman: M. R. H. Sadler. *Vice-Chairman:* C. H. Aslin. *Hon. Publicity Officer:* E. Jewitt. *Committee:* C. H. Bamford, L. A. Doxey, V. A. Gilman, F. H. Pooles, N. D. Wood. *Hon. Secretary:* C. S. Wheeler, 57, Evans Avenue, Allestree, Derby.

EDINBURGH GROUP (SCOTTISH AREA).

Chairman: N. G. Wilson. *Committee:* G. E. Collier, G. E. L. Comrie, J. B. Mackenzie, D. D. Melvin, G. Reid, M. G. Say. *Hon. Secretary:* S. G. Batt, 8, George Street, Edinburgh.

GLOUCESTER AND CHELTENHAM GROUP (WESTERN AREA)

Chairman: A. L. Morris. *Hon. Treasurer:* E. G. Purnet. *Committee:* W. A. Chard, J. F. Edgell, W. Holtam, J. Marshall, I. R. Morgan, L. C. Mitchell, B. C. Robinson, H. V. Sayce, W. R. Steel, A. G. Wedlake. *Hon. Secretary:* I. S. Freemantle, 11, St. Aldgate Street, Gloucester.

HALIFAX GROUP (NORTH MIDLAND AREA).

Chairman: A. E. Elson. *Hon. Treasurer:* L. M. Naylor. *Committee:* S. Bates, L. Birkhead, A. R. Buttery, F. Iredale, N. Nichol, W. K. Wade. *Hon. Secretary:* H. W. Lodge, c/o Public Lighting Offices, Halifax.

HUDDERSFIELD GROUP (NORTH MIDLAND AREA).

Chairman: J. W. Whitaker. *Vice-Chairman:* E. Lunn. *Committee:* R. Hardy. H. P. Ripley, W. Robinson, N. Singleton, J. T. Thornton, W. Turner, H. L. Walker. *Hon. Secretary:* E. Wood, 11, Long Grove Avenue, Dalton, Huddersfield.

LIVERPOOL GROUP (NORTH-WESTERN AREA).

Chairman: A. E. Darlington. *Vice-Chairman:* Harold Jones. *Hon. Treasurer:* W. T. Trace. *Committee:* L. G. Harris, S. Heywood, T. Jones, C. Logan, A. V. Milton, H. Moorhouse, S. Smedley, C. Waiting, T. Woods. *Hon. Secretary:* K. R. Macklay, 24, Dale Street, Liverpool, 2.

TEES-SIDE GROUP (NORTH-EASTERN AREA).

Chairman: W. E. Dalby. *Hon. Treasurer:* R. J. Patrick. *Committee:* E. A. Anderson, W. H. Ellerker, H. V. Field, F. L. Scaife, W. H. Smithson. *Hon. Secretary:* R. H. Batey, 14, Preen Drive, Acklam. Middlesbrough. Yorks.

Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

SUSTAINING MEMBERS:—

Electricity House, Ltd.....*Representative*: E. A. Fowler.
Bramhope, nr. LEEDS.

Smith Bros. (Rotherham), Ltd.....*Representative*: T. Latham.
14, High Street, ROTHERHAM.

CORPORATE MEMBERS:—

Bache, W. J. .....“Eythorne,” All Saints Road, CHELTENHAM.
Bannister, J. A. .....16, Beachcroft Gardens, Wembley, MIDDLESEX.
Bell, F. W. .....“Sheldon,” 10, Sandhurst Road, GLOUCESTER.
Birkhead, H. .....47, New Crown Street, HALIFAX.
Buglass, J. .....19, Paignton Avenue, NEWCASTLE-ON-TYNE, 4.
Corke, A. J. .....4, Grandison Road, LIVERPOOL, 4.
Crofts, W. S. .....111, Dean Road, Bo'ness, W. LOTHIAN.
Eden, P. N. .....Tree Tops, Park Avenue, Ruislip, MIDDLESEX.
Grainger, J. .....21, Heather Place, NEWCASTLE-ON-TYNE, 4.
Grant, J. K. .....Leith Dock Commission, Tower Place, LEITH.
Hardacre, W. .....1A, Aintree Road, Bootle, LIVERPOOL, 20.
Harris, E. S. .....92, Orchard Gate, Greenford, MIDDX.
Harvey, H. G. .....37, Upper Belmont Road, Bishopston, BRISTOL, 7.
Hawkins, A. .....129, Wallasey Village, Wallasey, CHESHIRE.
Hicks, A. E. .....22, All Saints Road, CHELTENHAM.
Hunter, T. D. .....Eastern Electric Service, Waverley Engineering Works, Norton Park, EDINBURGH, 7.
Jones, H. G. .....24, Junction Road, BATH.
Jones, H. E. .....127, Oxton Road, BIRKENHEAD.
Lockyer, E. N. .....10, Hillside Terrace, Ystrad Mynach, Hengoed, GLAM.
MacDonald, T. M. ...8, Wylie Avenue, Alexandria, DUMBARTONSHIRE.
Mant, L. W. .....“Beaulieu,” 28, Welbourne Road, Broadgreen LIVERPOOL.
Mills, R. V. .....19, King Edward Road, RUGBY.
Morrison, A. B. .....32, Netherby Road, EDINBURGH.
Nichols, H. C. .....1, St. Helena Road, Westbury Park, BRISTOL, 6.
Ollier, T. .....329, Clayton Road, Lidget Green, BRADFORD.
Pickthall, J. E.....Ensign Lamps, Ltd., Kent Street, Preston, LANCS.
Stenway, H. .....7, Macdowall Road, EDINBURGH.
Smith, C. D. .....5, Irby Road, BRISTOL, 3.
Smith, J. E. .....4, Airedale Cliff, Pollard Lane, Bramley, LEEDS.
Smith, J. R. L.....67, Vandeleur Avenue, EDINBURGH, 7.
Ridout, F. .....38, Regents Way, Bebington, CHESHIRE.
Sankey, G. H. .....Long View, Eildon Street, Galashields, SELKIRKSHIRE.
Vernon, W. Somerville .....26, Low y Dail, Rhiwbina, CARDIFF.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

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